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MISSOURI RIVER BASIN

Analysis of WATER AVAILABILITY on the MISSOURI RIVER Above CANYON FERRY RESERVOIR

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ANALYSIS OF WATER AVAILABILITY ON THE MISSOURI RIVER ABOVE CANYON FERRY RESERVOIR

by

Diana Fitz, Hydrologist

WATER SCIENCES BUREAU
WATER RESOURCES DIVISION

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

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TABLE OF CONTENTS

INTRODUCTION. 1

WATER RIGHTS AT CANYON FERRY. 2
    Water Rights Claimed and Used by WPRS. 2
    Water Rights Claimed and Used by MPC 6

HYDROLOGIC ANALYSIS 7
    Background 7
    Reservoir Operations 8
    Development of Water Use at Canyon Ferry Reservoir 9
    Relationship between Annual Water Use and Inflow 9
    Comparison of Probable Inflows with Prior Appropriations 9
    Comparison of Probable Inflows with Spills 15
    Determining the Time of Water Availability 15
    Conclusion 19

LIST OF TABLES

TABLE		PAGE
1	Beneficial Water Use at Canyon Ferry Dam	3
2	Maximum Beneficial Water use at Canyon Ferry (1953-1979)	4
3	Water Spilled at Canyon Ferry Dam	5
4	Reservoir Operations at Canyon Ferry Reservoir	10
5	Last Date of Spills at Canyon Ferry (1966-1979)	17

LIST OF FIGURES

FIGURE		PAGE
1	Development of Water Use at Canyon Ferry Reservoir	11
2	Beneficial Use vs. Annual Inflow at Canyon Ferry Reservoir	12
3a	Probability of Exceedence for Annual Inflows at Canyon Ferry Reservoir	13
3b	Probability of Inflow Meeting or Exceeding Beneficial Use at Canyon Ferry Reservoir	14
4	Spill vs. Annual Inflow at Canyon Ferry Reservoir	16
5	Flow Duration Hydrograph - Missouri River at Toston	18

INTRODUCTION

The Department of Natural Resources and Conservation (DNRC) Water Resources Division, has encountered a problem in processing applications for permits to appropriate water in the upper Missouri River basin above Canyon Ferry Reservoir. The Montana Power Company (MPC) and the Water and Power Resources Service (WPRS), formerly the U.S. Bureau of Reclamation (BOR), have objected to the applications, saying that any further appropriation of Missouri River water above the reservoir would infringe on their claimed rights to the water. As of November 1980, DNRC action on approximately thirty such applications had been postponed, pending preparation and analysis of this water availability study.

MPC operates nine hydroelectric and/or storage reservoirs in the upper Missouri River basin. Seven of these reservoirs are located on the main stem of the Missouri River below Canyon Ferry Reservoir. Objections by MPC to the applications state that no unappropriated water exists above Canyon Ferry Reservoir and that additional appropriations would deplete water needed for hydroelectric generation.

The formal objections of WPRS are similar to those of MPC and relate to operation of the agency's Canyon Ferry facilities. While MPC uses its plants strictly for electrical production, WPRS operates Canyon Ferry for multiple uses, as mandated in the construction authorizations for the Canyon Ferry Unit of the Missouri River Basin Project.[1] Besides flood control, the main uses for the water storage facility at Canyon Ferry have been electrical production and recreation. Small amounts of water also have been diverted to the Helena Valley for irrigation. WPRS contends that additional appropriations of water above Canyon Ferry Reservoir would deplete water needed for irrigation and energy production.

Both objectors agree that during certain months of some years, water exists in excess of their rights; however, the amounts of water involved, periods of availability, and regularity of availability are open to question. This report provides information that will help answer these questions. In addition, the report will be used to form a DNRC policy regarding the pending applications, as well as any future applications for appropriations above Canyon Ferry Reservoir.

WATER RIGHTS AT CANYON FERRY

Water rights in Montana with priority dates earlier than 1973 are based on historical water use. In this section, water use at Canyon Ferry by MPC and WPRS is summarized along with the rights claimed by each party. A more detailed analysis of water claimed by WPRS and MPC was prepared by Guse (1979).[2] A final determination of water rights will be handed down by the courts sometime in the future.

Water Rights Claimed and Used by WPRS

Canyon Ferry Dam was completed in 1953. Since that time, the 50-megawatt facility has been generating power, and the reservoir, by capturing spring runoff, has provided water users, both upstream and downstream (primarily MPC), with a reliable supply of water throughout the year. In 1959, WPRS began supplying water to the Helena Valley Irrigation Unit for irrigation and pumping power. Following devastating floods in 1964 and 1965, the U. S. Army Corps of Engineers was allotted the top 3 feet of the reservoir exclusively for flood control. Additionally, the reservoir has become a popular recreation area for Montanans and out-of-state visitors. These uses are listed to emphasize that Canyon Ferry is not strictly a hydropower facility. The measurable use of water (for irrigation and power) is enumerated in table 1. Table 2 shows the maximum beneficial water use at this facility.

Although attempts have been made to quantify WPRS' legal right to Canyon Ferry water, a final determination has never been reached. In a hearing on one water use permit application (4963-S411), the hearings examiner found, as stated in the Proposed Findings of Fact for the case, that WPRS was entitled to a maximum water draught of 7,000 cubic feet per second (cfs), based on hydropower generation and irrigation requirements (6,250 cfs for hydropower, and 750 cfs for irrigation).[3] WPRS has used 7,000 cfs on only one occasion--April 21, 1976. However, beneficial use exceeding 6,000 cfs is quite common when water is available.

WPRS defended its water need at the hearing by saying:

> "It is important that the Bureau be able to fill the reservoir each year and that such right be protected herein as the reservoir is expected to contain sufficient carry-over storage water to be able to meet a four-year critical period so as to enable the Bureau to meet its requirements, as well as, to enable the Bureau to release sufficient water to satisfy prior downstream requirements over such a four-year critical period."[4]

TABLE 1

BENEFICIAL WATER USE AT CANYON FERRY DAM[1]
(Thousands of acre-feet)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEARLY TOTALS	MONTHLY AVERAGES [2]
1953													0.0	0.0
1954			26.3	105.4	65.3	66.8	65.5	110.8	105.2	162.2	127.7	167.8	1002.9	100.3
1955	188.3	257.8	283.9	261.1	245.5	240.1	164.5	120.4	84.2	124.2	208.4	226.2	2404.8	200.4
1956	280.0	275.8	295.6	297.6	296.5	267.8	148.9	141.1	137.5	162.5	258.6	244.7	2086.6	233.9
1957	260.9	246.2	269.3	304.4	291.6	290.6	226.8	189.8	88.0	196.5	250.9	246.3	2861.4	238.5
1958	262.4	243.2	292.0	334.8	293.7	215.8	134.8	16.6	97.7	174.6	259.4	270.2	2595.3	216.3
1959	276.8	237.7	234.0	231.8	188.8	166.3	142.3	44.0	58.7	101.4	166.6	114.4	1952.9	162.7
1960	62.5	56.2	58.1	100.8	147.3	183.2	113.1	135.2	138.2	222.5	208.6	238.7	1665.2	138.8
1961	265.2	246.3	219.0	273.4	193.1	179.7	228.2	172.5	143.6	217.5	260.5	185.9	2584.7	215.4
1962	199.1	254.7	273.8	263.5	208.9	320.1	184.1	130.0	47.1	143.6	264.0	230.1	2520.0	210.0
1963	249.3	234.8	238.1	238.8	197.6	242.1	214.3	71.1	56.1	173.2	227.8	243.1	2386.2	198.8
1964	268.2	272.2	290.9	234.9	200.1	231.9	237.0	63.4	97.1	132.6	237.8	234.2	2500.3	208.4
1965	241.5	291.1	314.9	313.3	292.7	324.6	228.7	73.4	141.0	224.3	203.8	230.0	2879.2	239.9
1966	269.8	284.9	307.4	313.5	245.9	307.9	311.6	222.6	190.0	202.0	218.9	166.2	3040.5	253.4
1967	166.5	167.9	313.6	362.8	330.8	341.1	223.3	240.9	299.6	353.9	311.6	237.7	3349.8	279.1
1968	234.6	202.8	311.5	328.7	318.7	296.8	337.5	399.9	365.3	358.7	291.5	224.5	3660.5	305.0
1969	317.7	280.0	328.3	340.7	318.1	362.7	364.9	369.9	346.9	341.0	289.2	247.4	3906.0	325.5
1970	225.6	294.5	327.2	338.4	277.5	329.5	370.5	401.8	359.9	357.0	362.4	267.3	3911.8	326.0
1971	295.9	315.8	338.9	363.0	335.8	384.5	374.5	401.0	376.6	358.9	308.2	286.3	4139.2	344.9
1972	322.8	322.1	335.9	344.5	330.7	335.5	464.5	402.0	360.7	361.1	320.7	337.8	4129.7	344.1
1973	353.2	336.5	331.4	308.4	262.7	225.3	179.2	238.8	293.0	307.2	219.8	167.6	3213.2	267.8
1974	248.4	298.8	326.7	340.1	318.0	368.5	378.2	394.0	353.1	356.6	315.6	268.1	3966.3	330.5
1975	267.8	211.8	310.4	356.0	305.9	367.9	352.5	382.2	357.0	351.1	351.6	320.4	3934.4	327.9
1976	325.9	311.4	331.4	338.7	309.8	366.1	386.9	406.2	351.5	357.6	361.7	334.4	4181.5	348.5
1977	315.7	313.8	323.0	331.5	266.0	251.0	252.0	212.1	154.6	172.4	206.6	152.3	2951.2	245.9
1978	220.9	269.8	339.7	351.4	338.9	378.1	363.9	402.1	362.7	345.0	339.3	294.5	4006.3	333.9
1979	276.5	316.9	344.3	365.2	287.0	319.6	321.0	352.9	305.9	243.0	236.8	216.6	3488.5	290.7
MONTHLY AVERAGES [3]	255.8	261.7	283.2	297.8	264.1	283.2	255.8	234.0	218.1	249.6	261.9	266.6	3050.7	

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[1] Beneficial water use includes water run through the turbines to generate electricity, to pump water to the Helena Valley, and water for irrigation.

[2] Averages are based on 12-month denominator except for 1954, which has 10-month denominator reflecting initial use that year.

[3] October and November averages are based on 25-year denominator. December through September averages are based on 26-year denominator.

TABLE 2

MAXIMUM BENEFICIAL WATER USE AT CANYON FERRY (1953-1979)

	Largest Daily Average		Largest Monthly Average	
Month	cfs	Date	cfs	Year
October	5810	10/14/72	5755	1972
November	5720	11/4/72	5665	1972
December	6040	12/31/66	5610	1978
January	6120	1/28/79	5949	1979
February	6280	2/24/78	6113	1978
March	6240	3/7/78	6160	1978
April	7040	4/21/76	6512	1976
May	6970	5/14/76	6618	1976
June	6790	6/5/68	6150	1968
July	6020	7/31/68	5844	1968
August	6220	8/14/74	5892	1976
September	6340	9/30/72	5627	1976

Largest annual use of water at Canyon Ferry (water year 1976) was 4,181,500 acre-feet, which is equivalent to an average of 5,786 cfs for the entire year.

*cfs is the abbreviation for a flow measurement, cubic feet per second

*acre-feet is a volumetric measurement equivalent to one acre of water, one foot deep.

TABLE 3

WATER SPILLED[1] AT CANYON FERRY DAM
(Thousands of acre-feet)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEARLY TOTALS	MONTHLY[2] AVERAGES
1953						29.8	249.4	237.1	343.7	254.1	162.5	142.9	1419.4	202.8
1954	209.5	230.0	219.9	189.8	197.3	182.9	164.1	40.6					1434.0	119.5
1955		1.0								88.7	4.5		94.2	7.9
1956							225.4	388.8	410.6	87.5			1112.3	92.7
1957								1.4	567.6	126.1			695.1	57.9
1958							229.4	365.2	158.7	145.7			899.0	74.9
1959							2.5	355.8	570.5	220.7			1149.5	95.8
1960	302.9	492.8	631.9	90.5	17.9	91.7	324.0	350.5	260.7				2562.8	213.6
1961													0.0	0.0
1962									414.9	100.9			515.8	43.0
1963		45.6			71.8			411.6	828.6	160.3			1518.0	126.5
1964							13.2	368.3	872.4	347.7	7.7		1609.3	134.1
1965						43.2	261.3	600.2	570.6	409.8	43.3	117.0	2045.5	170.5
1966	345.2	189.8	48.3										583.4	48.6
1967									285.8	198.9			484.7	40.4
1968						255.3	56.1		124.5	49.1		34.3	519.3	43.3
1969	48.9	60.0				87.6	121.6	296.9	209.3	227.5			1051.8	87.7
1970							77.3	182.0	405.0	152.3			816.6	68.1
1971		0.2					150.9	376.0	113.3	198.0			839.4	69.9
1972	0.2						148.5	203.9	191.6	30.4			574.7	47.9
1973													0.0	0.0
1974								57.5	339.8	94.1			491.4	41.0
1975									333.6	628.4	47.1		1009.2	84.1
1976	34.0	147.6	100.1	30.2	35.4	104.2	259.0	425.4	364.6	84.9			1585.4	132.1
1977		10.2	8.4										18.6	1.5
1978					17.9	22.2	17.1	27.0	118.8	124.0			327.0	27.2
1979													0.0	0.0
MONTHLY[3] AVERAGES	36.1	45.3	38.7	11.9	13.1	30.2	85.2	173.7	277.2	138.1	9.8	10.9	716.9	

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[1] Water spilled includes water passed over or through dam in nonbeneficial use.

[2] Averages are based on 12-month denominator except for 1953, which has 7-month denominator reflecting initial closure that year.

[3] October through February averages are based on 26-year denominator. March through September averages are based on 27-year denominator.

Because the applicants eventually withdrew their request, the case was never resolved.

In order for water in the upper Missouri River to be considered available for appropriation, it must be water that is in excess of the water used by WPRS at Canyon Ferry. WPRS claims that no such water is available on a reliable basis and that water is never available throughout the entire irrigation season. To support this claim, WPRS submitted the information in table 3, which lists the water that has spilled through the dam (that is, passed through the dam with no apparent use) since 1953.

Water Rights Claimed and Used by MPC

WPRS (then the Bureau of Reclamation) built Canyon Ferry Dam to permit further irrigation development in the upper Missouri River basin. By creating the large Canyon Ferry Reservoir, the bureau could guarantee that MPC's downstream water rights would be met despite increased depletion of river water for agricultural use.[5] Because most of MPC's Missouri River hydroelectric facilities are downstream from the reservoir and are assured a fairly constant supply of water, WPRS is more likely than MPC to suffer from the effects of increased water depletion in the upper basin. After the reservoir was created, various agreements and binding contracts were drawn between MPC and WPRS to help protect the hydropower and water storage interests of both parties.

When the Canyon Ferry site was transferred to public ownership in 1949, MPC retained a claimed water right (October 1898) to 47,500 acre-feet of river water. As part of the transfer agreements, WPRS agreed to let a fairly constant 5,000 cfs pass through the dam so that MPC's downstream power plants would have a reliable source of water. In practice, however, this release is rather flexible depending on water supply and day-to-day operations.

In 1972, the Agreement for Coordination of Hydroelectric Operations of the United States of America and the Montana Power Company was signed. It was agreed in the document that generating facilities and flows from reservoirs "must be coordinated to achieve as much power production as possible from both systems," to "make available to each party its optimum usable energy production at all time," and "to assure the availability and release on a preplanned basis of all water, exclusive of certain nonpower uses, during the critical period."

In view of the agreements and contracts between WPRS and MPC, it appears that if WPRS' rights are met at Canyon Ferry, MPC's rights also will be satisfied.

HYDROLOGIC ANALYSIS

Before a water use permit can be granted, DNRC must determine that there is water available in the quantity necessary at the time needed. This analysis will attempt to quantify the answers to these questions for the upper Missouri River basin. Objectives of this analysis were:

- -- to determine how much, if any, water is available for appropriation above Canyon Ferry Dam
- -- to estimate the probable occurrence of available water
- -- to predict the time of the year when water will be available.

Since one of the main functions of the dam is to store water during one part of the year for release during drier periods, it was decided that water availability should be analyzed on an annual basis. In any shorter time interval, yearly changes in storage confuse the issue. The water year which begins October 1 and ends September 30, was selected because October 1 is generally the low point in the hydrologic cycle. Water typically is stored from October through June and is released from July through September.

Background

Two sets of daily records were instrumental in the hydrologic analysis of Canyon Ferry Reservoir. First, are those records kept by the U. S. Geological Survey for a gaging station located near Toston, approximately 43 miles upstream from Canyon Ferry Dam. Continuous flow records were compiled from 1911 to 1917 and from 1941 to the present. The station's gage measures nearly all of the water flowing into Canyon Ferry Reservoir.

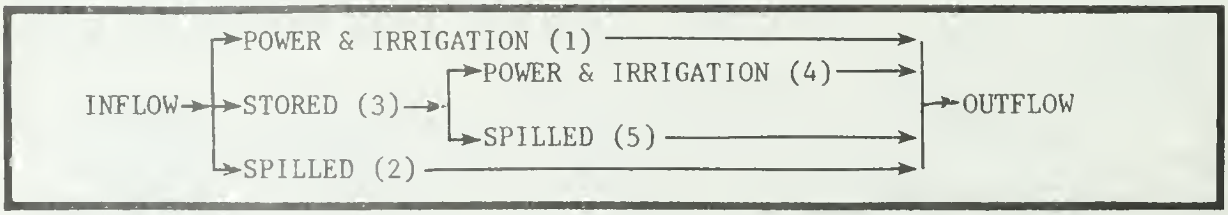
Second are those data documenting all water used by WPRS at the dam (power generation and irrigation), all water spilled through the river outlets, and changes in the amount of water stored in the reservoir. These data are available from WPRS for the period from the completion of the dam to the present (1953-1979). Net inflow to the reservoir can be calculated as the sum of change in reservoir storage and the total discharge. This computed figure is more exact than the inflow measurement at Toston because it takes into account any gains or losses (including evaporation, precipitation, bank storage, and contributions of tributaries) which take place between Toston and the dam. A very good correlation exists between the flow measured at Toston and the computed inflow ($r^2 = .98$). The data suggest that about 4% more water flows into Canyon Ferry Reservoir than is measured near Toston.

The computed inflows and other data provided by WPRS were used for most of the analyses. However, USGS flow data recorded at Toston (adjusted by 4%) were used to calculate probable inflows to the reservoir. The longer record period of the Toston data provides a more accurate assessment of historical inflows.

Reservoir Operations

Canyon Ferry Dam and Reservoir were designed to impound water during the high spring runoff of the upper Missouri River basin and release this water throughout the year as needed. This redistribution of flow provides a reliable supply of water, both for power generation and irrigation. The large reservoir provides enough additional storage to satisfy prior downstream requirements over a 4-year critical period. Details concerning the use of water from the carry-over storage are described by Thompson (1979).[7]

In its simplest form, the operation at Canyon Ferry can be described by the figure shown below. All water which comes into the system is either (1) used for power generation and/or irrigation in the Helena Valley, (2) spilled through the river outlets, or (3) stored in the reservoir. Water that has been stored may later be (4) used to produce power or for irrigation, or (5) spilled through the river outlets. Any direct use of the water, (1) and (4), is clearly a beneficial use.



Water spilled through the river outlets, (2) and (5), could have been appropriated. For the remainder of this analysis the term BENEFICIAL USE will refer to all beneficial uses, (1) and (4), and the term SPILL will refer to water spilled through the river outlets, (2) and (5). Water remaining in storage cannot be classified until it leaves the system.

Table 4 quantifies annual reservoir operations for each water year (1953-1979). These water use data were analyzed several ways to promote a better understanding of reservoir operations.

Development of Water Use at Canyon Ferry Reservoir

In figure 1, total annual water use for power generation and irrigation was plotted against time. The figure suggests that water use peaked in 1970 and then leveled off. Variations in water use after 1970 are due primarily to variations in annual inflow rather than changes in energy demand. To show the overall trend in water demand, 5-year averages also were plotted.

Relationship between Annual Water Use and Inflow

The large variation in water use seen in figure 1 promoted an interest in the relationship between water use and inflow. Beneficial use is plotted as a function of annual inflow in figure 2. Only the data for 1966 through 1979 were used in this analysis because WPRS appeared to be maximizing its water use during this period. The data suggest that during low flow years all of the inflow is beneficially used. When inflow exceeds approximately 3,550,000 acre-feet per year, beneficial use is no longer as great as inflow and some of the water is "wasted," or spilled. However, even during years of higher flows, beneficial use is still a function of inflow. The data suggest an increase of 300,000 acre-feet of water use for every 1,000,000 acre-feet of inflow above 3,550,000 acre-feet. Beneficial use of water is almost never greater than the annual inflow.

Comparison of Probable Inflow with Prior Appropriations

The annual yield measured at Toston, plus the 4% correction (for the 44 years of record), was used to develop a probability curve. The result is the diagonal line shown in figure 3a. An example for interpretation of the graph is shown on the figure. By following the arrows, it can be read that approximately 80% of the time the annual yield at Canyon Ferry will be greater than or equal to 3,300,000 acre-feet of water.

Since the amount of water that has already been appropriated for instream use at Canyon Ferry is still open to some debate, three different quantities were used for comparison. These are shown in figure 3b. WPRS claims that it is entitled to a continuous flow of 7,000 cfs. If this flow were used every

TABLE 4

RESERVOIR OPERATIONS AT CANYON FERRY RESERVOIR
(Thousands of acre-feet/year)

		From Inflow			From Storage		
Year	Net Inflow	Irrigation & Power	Spills	Storage	Irrigation & Power	Spills	Total Outflow
1955	2961.7	2404.8	94.2	462.6	0.0	0.0	2499.1
1956	3821.7	2806.6	1015.1	0.0	0.0	97.2	3918.9
1957	3525.9	2861.4	664.5	0.0	0.0	30.6	3556.6
1958	3460.5	2595.3	865.2	0.0	0.0	33.8	3494.2
1959	3379.9	1952.9	1149.5	227.5	0.0	0.0	3102.4
1960	3906.2	1665.2	2241.0	0.0	0.0	321.8	4228.0
1961	2200.1	2200.1	0.0	0.0	384.7	0.0	2584.8
1962	3692.9	2520.1	515.8	657.0	0.0	0.0	3035.9
1963	3791.9	2386.2	1405.7	0.0	0.0	112.3	3904.2
1964	4207.9	2500.3	1609.3	98.3	0.0	0.0	4109.6
1965	4991.4	2879.2	2045.5	66.7	0.0	0.0	4924.7
1966	2957.4	2957.4	0.0	0.0	83.1	583.4	3623.9
1967	4210.7	3349.8	484.7	376.2	0.0	0.0	3834.5
1968	4342.0	3660.5	519.3	152.2	0.0	0.0	4189.8
1969	4830.5	3906.0	924.5	0.0	0.0	127.3	4957.8
1970	4748.6	3911.8	816.6	20.2	0.0	0.0	4728.4
1971	5031.9	4139.2	839.4	53.3	0.0	0.0	4978.6
1972	4514.1	4129.7	384.4	0.0	0.0	190.3	4704.4
1973	3364.6	3213.2	0.0	151.4	0.0	0.0	3213.2
1974	4356.3	3966.3	390.4	0.0	0.0	101.4	4457.7
1975	5184.1	3934.4	1009.2	240.9	0.0	0.0	4943.6
1976	5661.3	4181.5	1479.8	0.0	0.0	105.6	5766.9
1977	2953.6	2951.2	2.4	0.0	0.0	16.2	2969.8
1978	4288.4	4006.3	281.1	0.0	0.0	44.9	4333.3
1979	3488.5	3488.5	0.0	0.0	88.1	0.0	3576.6

Figure 1

Development of Water Use at Canyon Ferry Reservoir

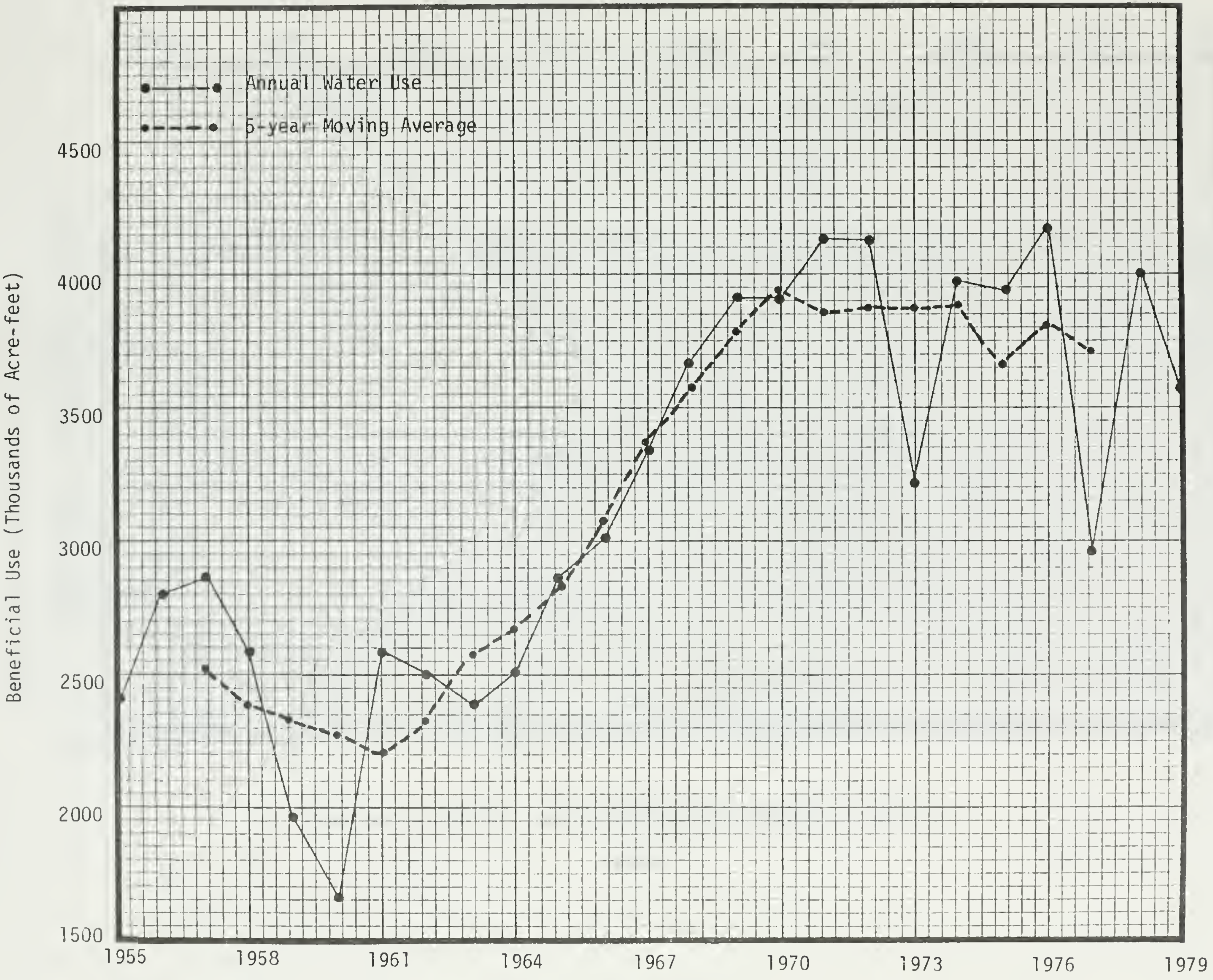


Figure 2

Beneficial Use vs. Annual Inflow at Canyon Ferry Reservoir

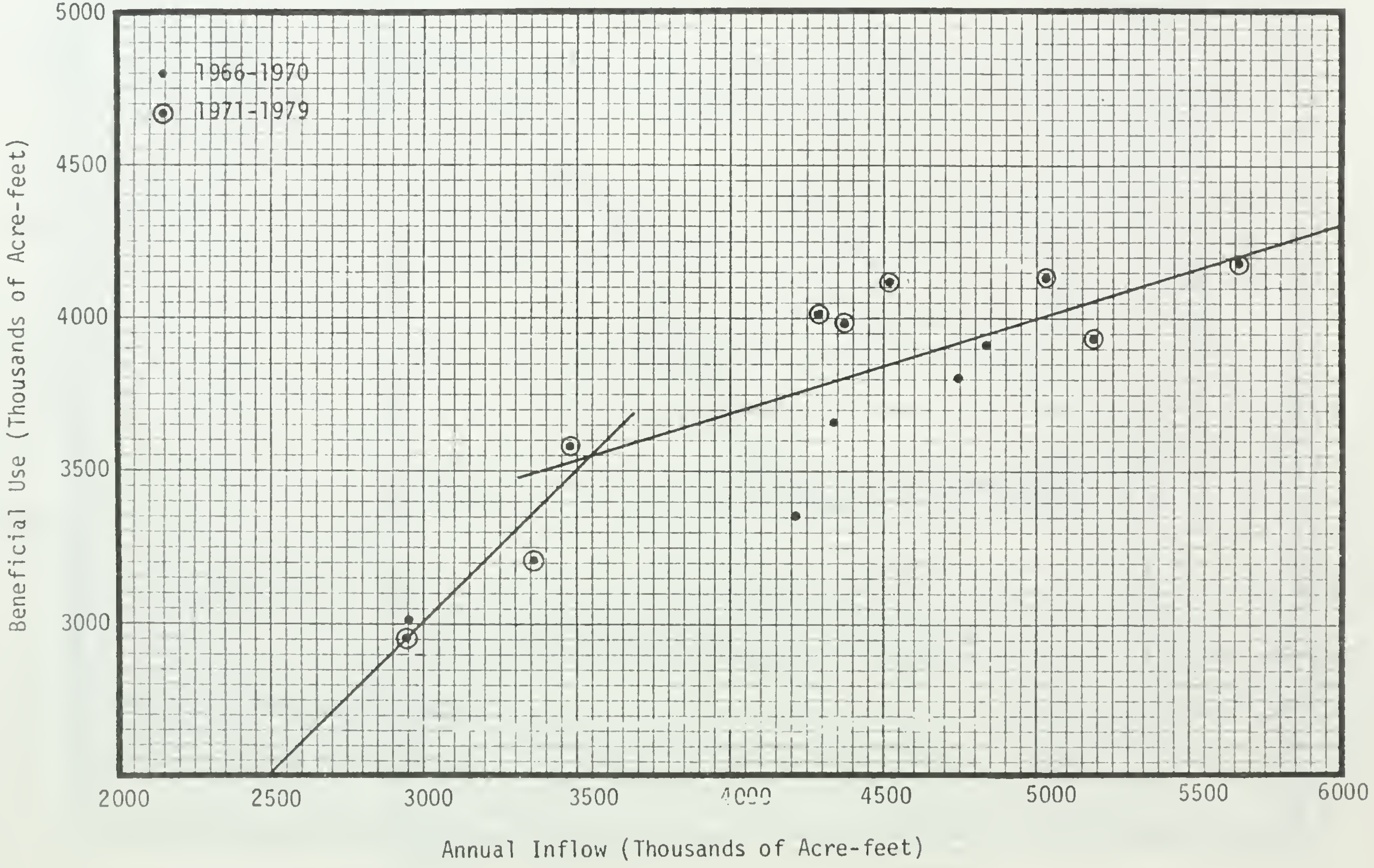


Figure 3a

Probability of Exceedence for Annual Inflows
at Canyon Ferry Reservoir
(Log-Normal Distribution)

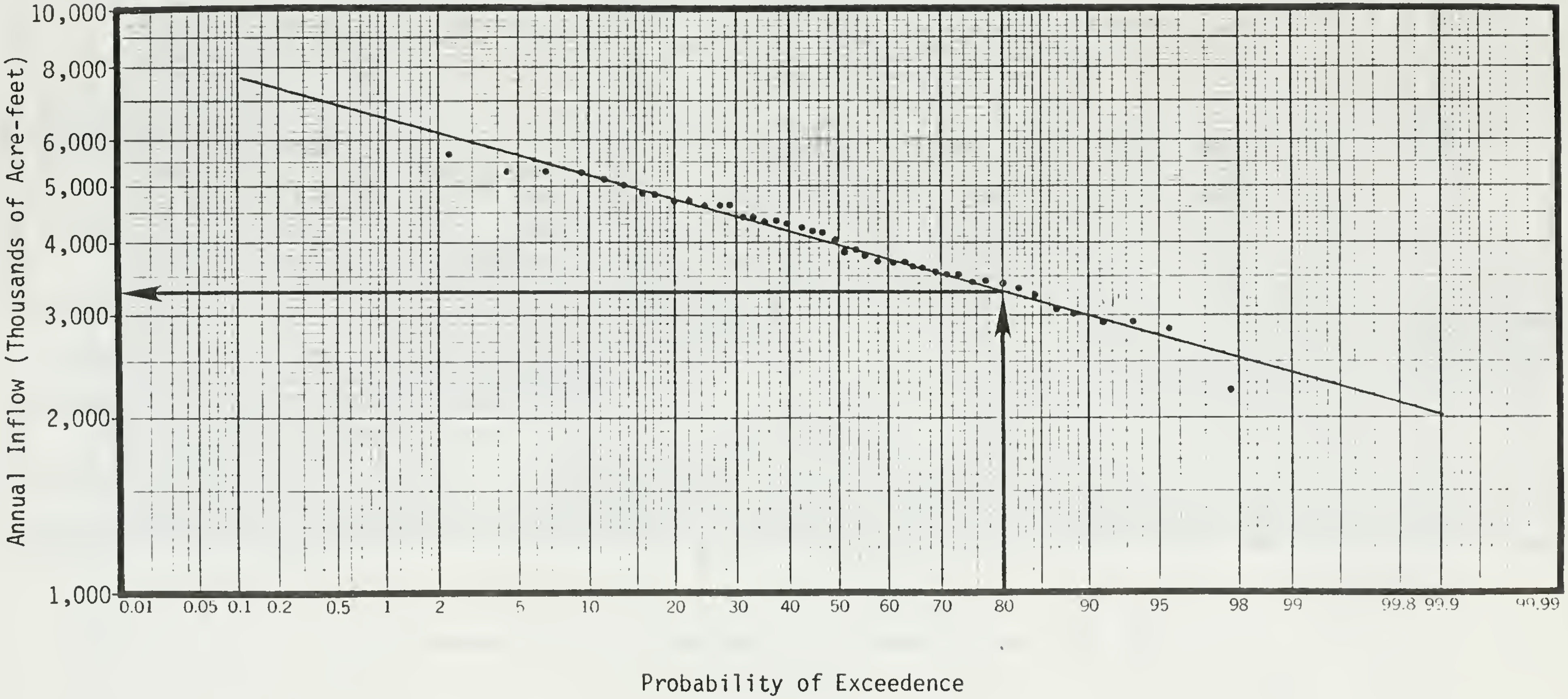
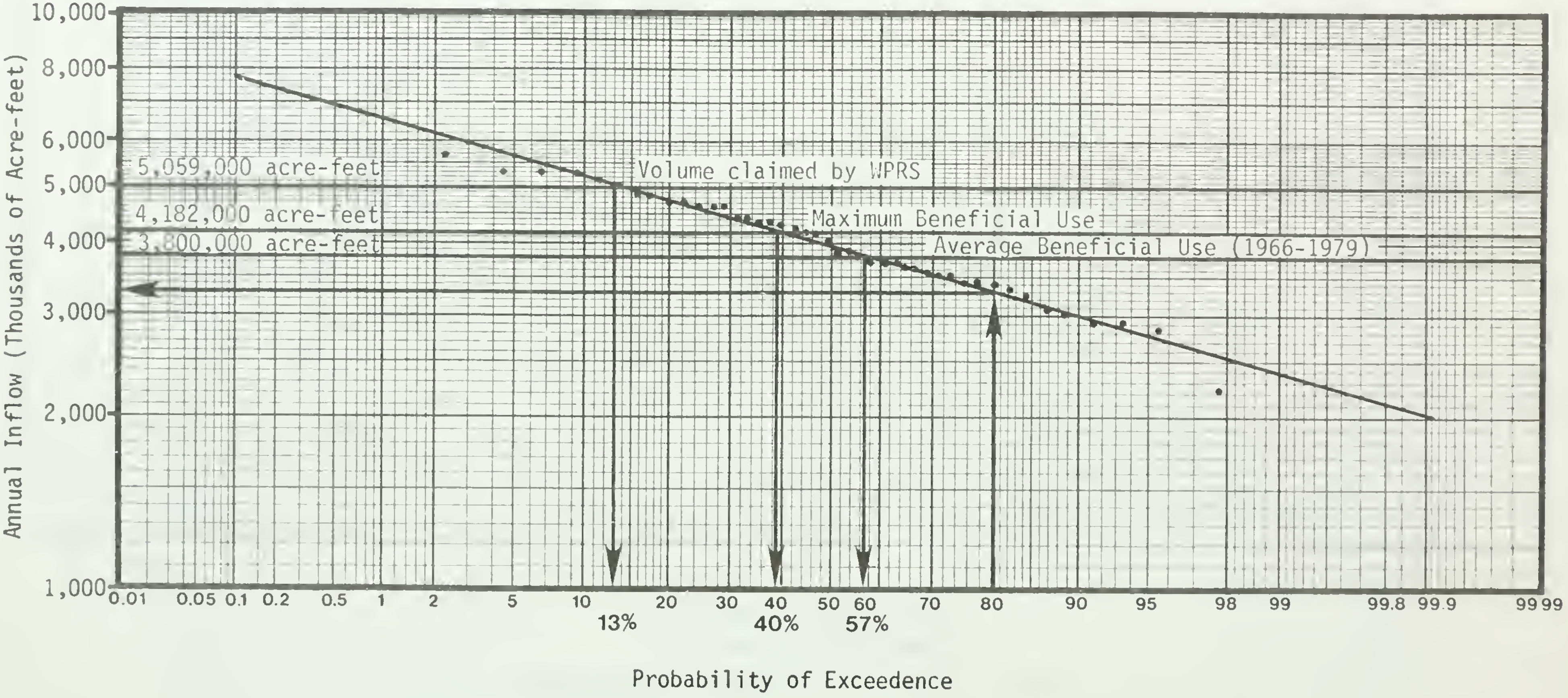


Figure 3b

Probability of Inflow Meeting or Exceeding Beneficial Use
at Canyon Ferry Reservoir



day of the year, WPRS would use 5,059,000 acre-feet of water each year. To date, however, the most water ever used in a year is 4,182,000 acre-feet. The average volume of water used for the period 1966-1979, was approximately 3,800,000 acre-feet per year. By comparing the volumes of use to the probability of inflow, the likelihood that annual inflow will meet or exceed the volume of water used can be read directly from the graph. Figure 3b shows that 13% of the time, annual inflow was greater than the water right claimed by WPRS, and that 40% of the time, inflow exceeded the actual maximum beneficial use. If the annual yield of the upper Missouri River basin continues to follow this trend, these figures should be representative of the future.

Comparison of Probable Inflows with Spills

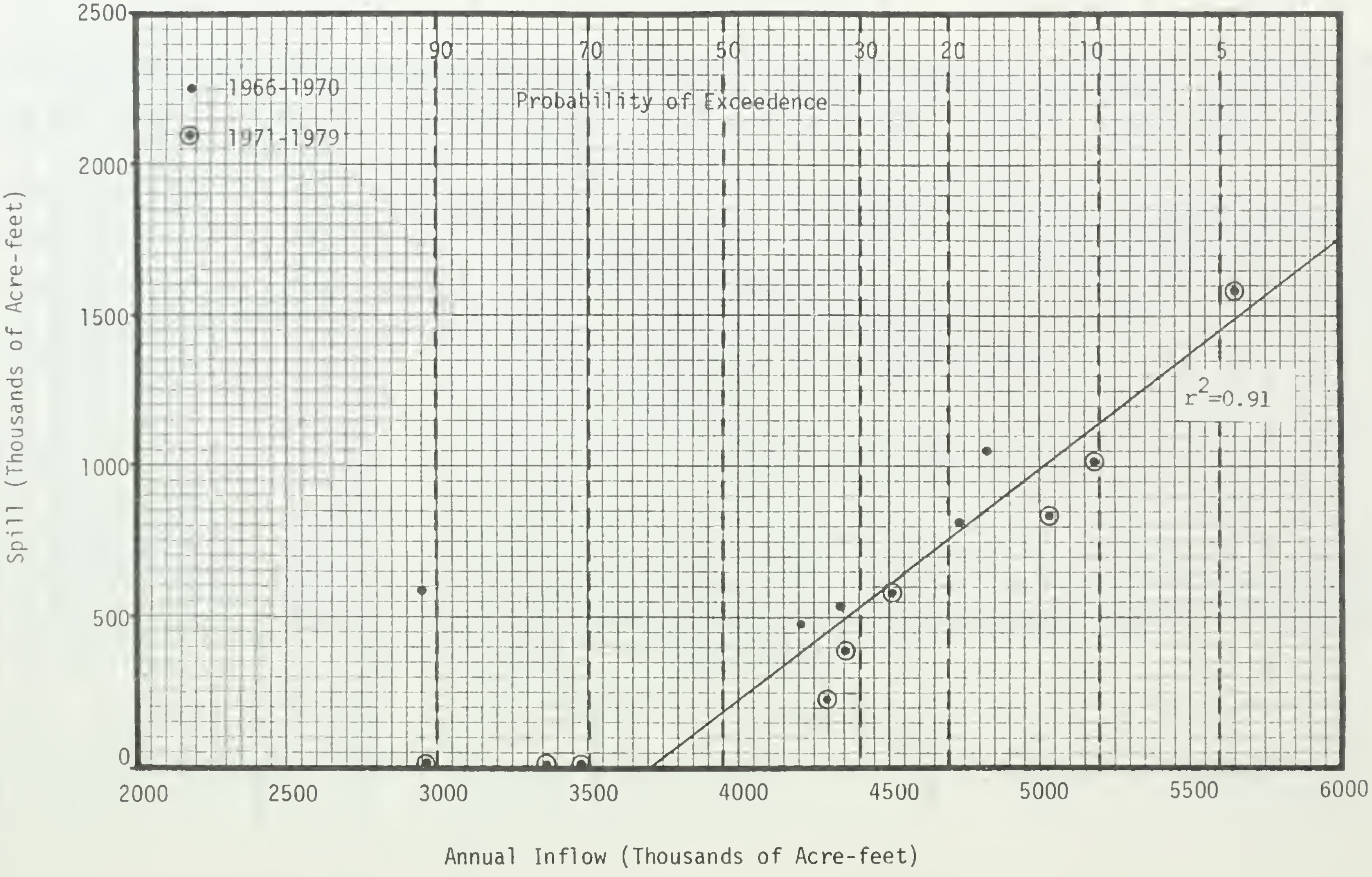
Another way to determine the amount of water available for appropriation is to assume that any water spilled at Canyon Ferry is available for appropriation. Consequently, a study of the spills as they relate to inflows was prepared. The results are shown in figure 4. An apparent relationship exists between the amounts spilled and the annual inflow for the period, 1966-1979. The figure suggests that with inflow less than 3,700,000 acre-feet there is no spill. With inflows above 3,700,000 acre-feet, water is spilled in amounts proportional to the increase in inflow. By comparing this figure with the information in figure 3a, the probability of spill volumes can be determined. The probability that inflow will exceed water use is shown on the upper axis. These probabilities also correspond to the matching spill. For instance, no spills can be expected 40% of time, and spills greater than or equal to 440,000 acre-feet can be expected 30% of the time.

Determining the Time of Water Availability

The last step in this analysis was to determine the time of water availability. Water availability usually begins sometime in the spring after WPRS knows that runoff will be sufficient to fill the reservoir, and lasts until the inflow is no longer greater than WPRS' water use. Once WPRS is sure that the reservoir will fill (following snowpack and spring runoff predictions), the opening date for appropriation is not critical. As long as the reservoir is going to fill, it makes little difference on which day it reaches capacity. However, as soon as the inflow is less than the daily water use, excess water has already been spilled and there is clearly no water left for appropriation. Thus, the closing date is critical.

Figure 4

Spill vs. Annual Inflow at Canyon Ferry Reservoir



Two different methods were used to determine the closing date for water availability. Each provides an estimate of the last date for water appropriation. These analyses are based on probabilities. In other words, the closing date depends on the yield of the basin in that particular year; in approximately 4 out of 10 years, no water will be available for appropriation.

The first analysis is very simple. It amounts to studying the spills from the period 1966-1979, and finding the date of the last spill. (The last spill corresponds with the latest date on which the inflow is less than the beneficial use of water). Table 5 lists the last date of spills. The average date is July 19; standard deviation from this date is 8 days.

TABLE 5
LAST DATE OF SPILLS AT CANYON FERRY (1966-1979)

Year	Date of Last Spill
1979	---
1978	July 25
1977	---
1976	July 12
1975	August 15
1974	July 14
1973	---
1972	July 6
1971	July 17
1970	July 18
1969	July 21
1968	July 15
1967	July 24
1966	---

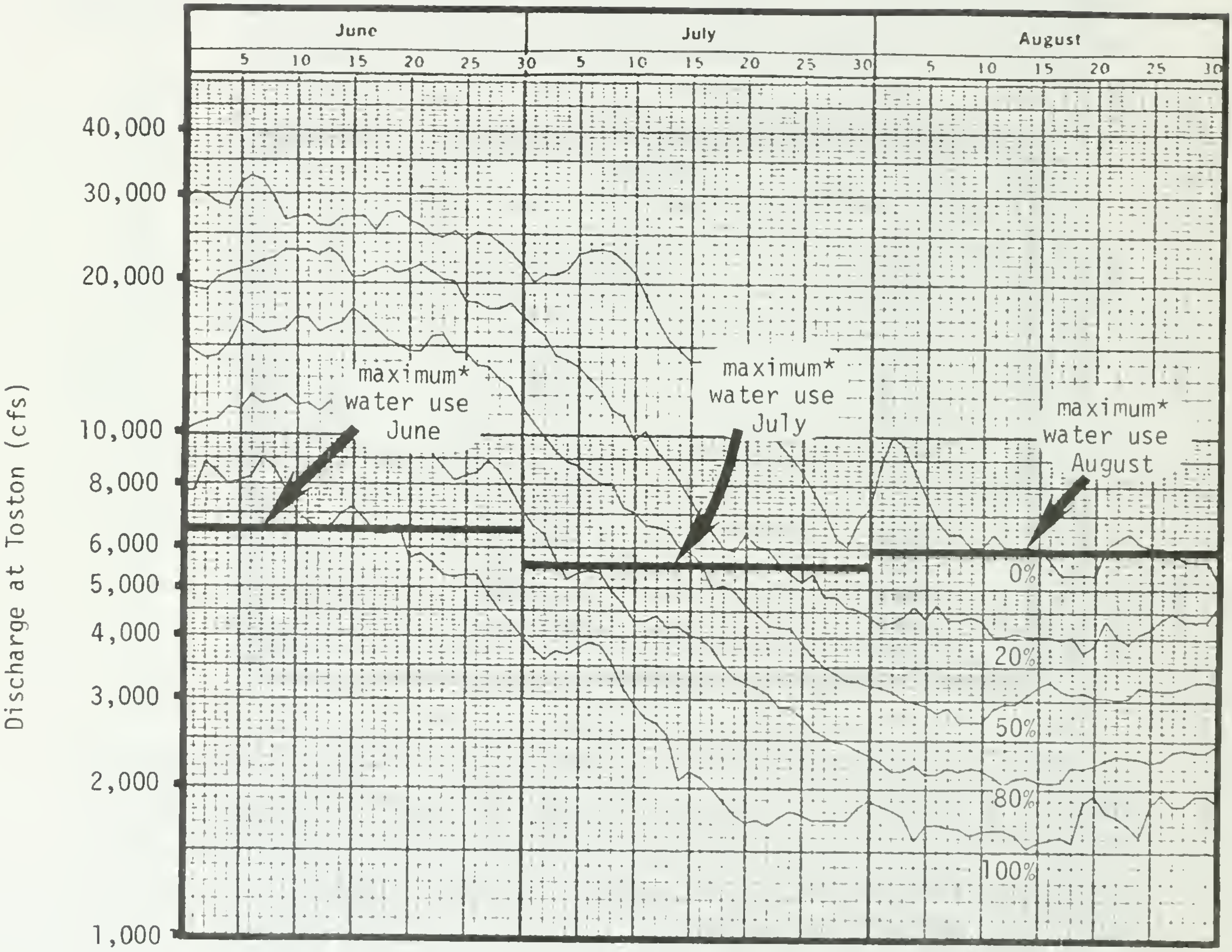
The problem with this analysis is that the short period of record (14 years) seems to cover a period when inflows were greater than should be expected. Table 5 shows that there were no spills during 4 of the last 14 years, even though it has been predicted that 40% of the time, or 6 out of 15 years, there should be no spills.

The second analysis uses a comparison of the daily inflow probability (based on 29 years of record when annual inflow exceeded 3,700,000 acre-feet) and 1950-1979 daily water use data. Figure 5 is a duration hydrograph for the

Figure 5

Flow Duration Hydrograph - Missouri River at Toston

(29 high flow years from 1911 to 1979)



* 6,790 cfs at Canyon Ferry ≈ 6,530 cfs at Toston (June)
6,020 cfs at Canyon Ferry ≈ 5,790 cfs at Toston (July)
6,220 cfs at Canyon Ferry ≈ 5,980 cfs at Toston (August)

flows measured at Toston for the months of June, July, and August. The bottom line is the lowest flow recorded on any given day (100% probability of exceedence). The top line is the highest flow recorded on each day (0% probability of exceedence). The three remaining lines represent, respectively, the 80%, 50%, and 20% probabilities of exceedence.

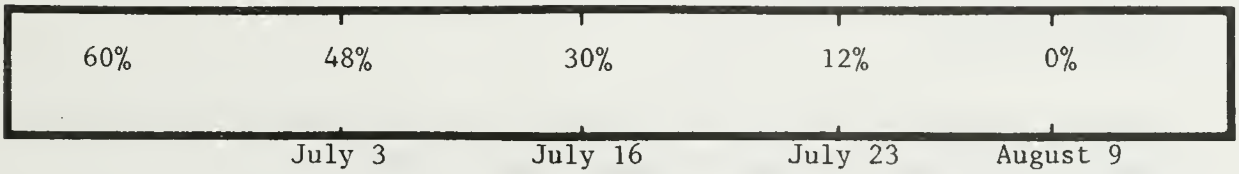
By comparing the duration hydrograph with the maximum daily use that has occurred during the months of June, July, and August (6,780 cfs, 6,020 cfs, and 6,220 cfs, respectively), the likely extent of the appropriation period can be determined. The figure indicates that in the years when water is available (e.g. the reservoir is full or filling):

-- 80% of the time there will be water after July 3
-- 50% of the time there will be water after July 16
-- 20% of the time there will be water after July 23
-- 0% of the time there will be water after August 9.

Actual determination of the closing date will depend on actual inflows and use in a given year.

Conclusion

By combining the results of the preceeding analyses, a rough picture of water availability can be produced. That picture is shown below. Since no spill (no available water) is expected in 40% of the years, water for appropriation probably will be available in only 60% of the years. As the run-off season progresses the probability of available water decreases. After August 9, water is essentially never available for appropriation.



Footnotes

1. Flood Control Act of 1944, Public Law 534; U.S. Senate Documents 191 and 247.

2. Guse, Ronald, A Report on Application No. 4963-S411..., DNRC, Water Rights Bureau, 1979.

3. Montana Department of State Lands, Proposed Findings of Fact, Application No. 5963-S411. 1976.

4. "Critical Period" was defined as the multi-month period, determined for the Coordinated WPRS-MPC System under adverse stream flows of historical record, collected to the level of development required for study purposes during which the least amount of estimated firm energy load can be supplied from the Coordinated System. To date, the "critical period" has been compared to the probable inflow conditions at Canyon Ferry Reservoir from 1935 to 1938, inclusive.

5. U.S. Bureau of Reclamation, Report on the Three Forks Division, September 12, 1958.

6. Contract no. 14-06-600-476A, Agreement, Coordination of Electric Operations, Upper Missouri River, United States of America and The Montana Power Company, March 30, 1972.

7. Thompson, Ronald, Bureau of Reclamation Water Use at Canyon Ferry Reservoir, DNRC, Water Sciences Bureau, in-house report, 1979.

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MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
DNRC

32 SO EWING
HELENA, MONTANA 59620

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